Wood Preservative Formulations

This invention relates to preservatives for wood and other materials, in particular to preservative formulations which contain an oxathiazine.

The use of oxathiazines in wood preservation is known (WO 95/06043 of Uniroyal Chemical Company, Inc.). These oxathiazines are most active against the soft rot fungi *Ascomycotina* and *Deuteromycotina*. These organisms are often responsible for significant degradation of wood in practice (Eaton and Hale (1993)).

As with most individual active ingredients, oxathiazines by themselves do not provide protection against all fungi, bacteria, and other microorganisms which it is desirous to protect wood or other materials against. Therefore, WO 95/06043 discusses the possibility of enhancing the spectrum of activity by addition of other active ingredients, binding agents, co-solvents etc.

Organic wood preservative formulations such as those containing oxathiazines are expensive to formulate and manufacture and improvements in their performance against fungi, particularly *Ascomycotina* and *Deuteromycotina*, would therefore be of benefit to the wood preservative industry.

Surprisingly, it has been found that by addition of certain other organic biocides, the efficacy of the oxathiazine-based formulations is significantly increased. In the case of some oxathiazines which have on their own poor efficacy, the addition of other organic biocides results in formulations having excellent efficacy, particularly against *Ascomycotina* and *Deuteromycotina*.

We have found that for an increase in activity of oxathiazine containing formulations against *Ascomycotina*

and *Deuteromycotina*, it is not a requirement that the additional organic biocides themselves have good activity against these fungi. A synergistic relationship has been observed, whereby oxathiazines and other organic biocides having individually moderate or poor efficacy against *Ascomycotina* and *Deuteromycotina*, when present together in a formulation provide a highly effective wood preservative agent.

The additional organic biocide is a quaternary ammonium compound or a triazole compound.

According to one aspect therefore, the present invention provides a preservative composition comprising, in synergistic proportions, an oxathiazine compound plus one or more of a quaternary ammonium compound and a triazole compound.

Particularly preferred compositions according to the invention comprise, in synergistic proportions, an oxathiazine compound, a quaternary ammonium compound and a triazole compound.

In a further aspect, the invention provides a method of preserving wood or other material which comprises applying to the wood or other material a composition comprising an oxathiazine compound plus one or more of a quaternary ammonium compound and a triazole compound in synergistic proportions.

The other materials besides wood which can benefit from treatment with the formulations of the invention include cellulosic material such as cotton. Also, leather, textile materials and even synthetic fibres, hessian, rope and cordage as well as composite wood materials. For convenience, the invention will be described with reference to the treatment of wood but it will be appreciated that other materials may be treated analogously.

The application of these compositions may be by dipping, spraying, brushing or other surface coating means or by high pressure or double vacuum impregnation

into the body of the wood or other material, all being techniques well known to the man skilled in the art. Impregnation under pressure is particularly advantageous when the substrate is wood or a wood composite material which is made to become wet during its life, for example, wood for window frames, timber used above ground in exposed environments such as decking and timber used in ground contact or fresh water or salt water environments.

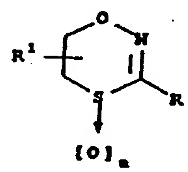
According to a further aspect of the invention there is provided the use of a quaternary ammonium compound or a triazole to enhance the activity of an oxathiazine against *Ascomycotina* and *Deuteromycotina*.

Substrates made of wood or other material which have been treated with a composition or by a method according to the invention as described herein, comprise further aspects of the present invention.

Certain compositions according to the invention are particularly advantageous from an environmental point of view, as they provide excellent heavy metal free compositions for protecting wood when it is in contact with soil, as the oxathiazine additionally protects the wood against soil bacteria such as Alcaligenes, Bacillus, Clostridium, Pseudomonas, etc.

Preferably, the compositions are applied to timber components before they are used in construction but they can also be used remedially as a curative action in preventing continued wood degradation or defacement.

Oxathiazine compounds for use in the present invention include, for example, oxathiazine compounds of formula (I)



(I)

wherein n is 0, 1 or 2; R^1 is hydrogen, C_1-C_4 linear or branched alkyl, or benzyl; and

R is:

(a) phenyl; naphthyl; phenyl substituted with 1 to 3 of the following substituents:

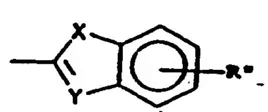
hydroxyl, halo, C_1-C_{12} alkyl, C_5-C_6 cycloalkyl, trihalomethyl, phenyl, C_1-C_5 alkoxy, C_1-C_5 alkylthio, tetrahydropyranyloxy, phenoxy, (C_1-C_4 alkyl)carbonyl, phenylcarbonyl, C_1-C_4 alkylsulfinyl, C_1-C_4 alkylsulfonyl, carboxy or its alkali metal salt, (C_1-C_4 alkoxy)carbonyl, (C_1-C_4 alkyl)aminocarbonyl, phenylaminocarbonyl, tolylaminocarbonyl, morpholinocarbonyl, amino, nitro, cyano, dioxolanyl, or (C_1-C_4 alkoxy)iminomethyl;

pyridinyl; thienyl, preferably when n is not 2; furanyl; or thienyl or furanyl substituted with 1 to 3 of the following groups:

alkyl, alkoxy, alkylthio, alkoxycarbonyl, halogen, trihalomethyl, cyano, acetyl, benzoyl, nitro, formyl, alkoxyaminomethyl, phenyl, or phenylaminocarbonyl, wherein the alkyl or alkoxy moiety is C_1-C_4, linear or branched;

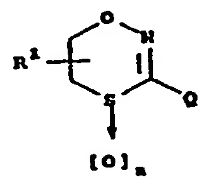
or

(b)



wherein X is oxygen or sulfur; Y is nitrogen, -CH-, or -C(C_1-C_4 alkoxy)-; and R" is hydrogen or C_1-C_4 alkyl.

Preferably the oxathiazine compound has the formula (II)

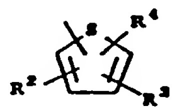


(II)

wherein n is 0, 1 or 2, R^1 is hydrogen, C_1-C_4 linear or branched alkyl, or benzyl; and

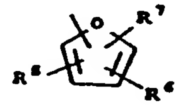
Q is:

(a)



wherein R^2, R^3 and R^4 are, individually, hydrogen, alkyl, alkoxy, alkylthio, alkoxycarbonyl, halogén, trihalomethyl, cyano, acetyl, formyl, benzoyl, nitro, alkoxyaminomethyl, phenyl, or phenylaminocarbonyl, wherein the alkyl or alkoxy moieties are all C_1-C_4, linear or branched, with the proviso that at least one of R^2, R^3 or R^4 must be other than hydrogen;

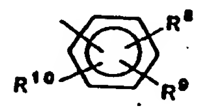
(b)



wherein R^5, R^6 and R^7 are, individually, hydrogen, C_1-C_4 alkoxy, C_1-C_4 alkylthio, halogen, trihalomethyl, cyano, acetyl, formyl, benzoyl, nitro, phenyl, or

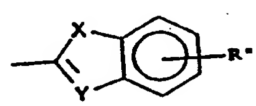
phenylaminocarbonyl, with the proviso that at least one of R^5, R^6 or R^7 must be other than hydrogen;

(c)



wherein R^8, R^9 and R^{10} are, individually, hydroxyl, halo, C_1-C_{12} alkyl, C_5-C_6 cycloalkyl, trihalomethyl, phenyl, C_1-C_5 alkoxy, C_1-C_5 alkylthio, tetrahydropyranyloxy, phenoxy, (C_1-C_4 alkyl)carbonyl, phenylcarbonyl, C_1-C_4 alkylsulfinyl, C_1-C_4 alkylsulfonyl, carboxy or its alkali metal salt, (C_1-C_4 alkoxy)carbonyl, (C_1-C_4 alkyl)aminocarbonyl, phenylaminocarbonyl, tolylaminocarbonyl, morpholinocarbonyl, amino, nitro, cyano, dioxolanyl, or (C_1-C_4 alkoxy)iminomethyl; or

(d)



wherein X is oxygen or sulfur; Y is nitrogen, -CH-, or -C(C_1-C_4 alkoxy)-; and R" is hydrogen or C_1-C_4 alkyl.

More preferably, the oxathiazine is a compound of formula II wherein

R^1 is hydrogen or C_1-C_4 alkyl; n is 1 or 2;

R^2, R^3 and R^4 are, individually, hydrogen, C_1-C_4 alkyl, halo, (C_1-C_4 alkoxy)-carbonyl, or cyano, with the proviso that at least one of R^2, R^3 and R^4 must be other than hydrogen;

R^5, R^6 and R^7 are, individually, hydrogen, halo or cyano, with the proviso that at least one of R^5, R^6 and R^7 must be other than hydrogen;

R^8, R^9 and R^{10} are C_1-C_4 alkyl, C_1-C_4 alkoxy, nitro, halo, trihalomethyl, or (C_1-C_4 alkoxy)-carbonyl; X is

sulfur; and R" is hydrogen.

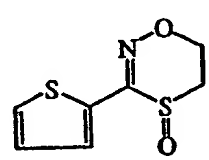
More preferred are those compounds of formula (II) wherein R^1 is hydrogen; n is 1 or 2;

R^2, R^3 and R^4 are, individually, hydrogen, methyl, ethyl, bromo, chloro, ethyl carboxylate, or cyano, with the proviso that at least one of R^2, R^3 and R^4 must be other than hydrogen;

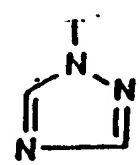
R^5, R^6 and R^7 are, individually, hydrogen, bromo, chloro, or cyano, with the proviso that at least one of R^5, R^6 and R^7 must be other than hydrogen;

R^8, R^9 and R^{10} are methyl, ethyl, nitro, fluoro, chloro, or trifluoromethyl.

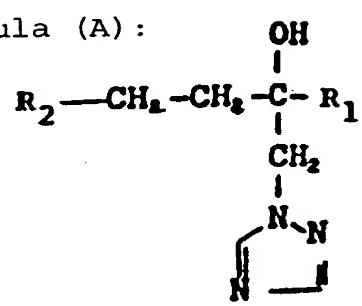
The most preferred oxathiazine compounds for use in the compositions and methods of the present invention are 3-(benzo[b]thien-2-yl)-5,6-dihydro-1,4,2-oxathiazine 4-oxide, hereinafter referred to as bethoxazin and 5,6-dihydro-3-(2-thienyl)-1,4,2-oxathiazine, 4-oxide,



Preferably the triazole compound contains the triazole group



Advantageously, the triazole compound is selected from compounds of formula (A):



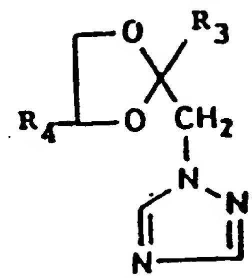
(A)

wherein R_1 represents a branched or straight chain

C_{1-5} alkyl group (e.g. t-butyl) and R_2 represents a phenyl group optionally substituted by one or more substituents selected from halogen (e.g. chlorine, fluorine or bromine) atoms or C_{1-3} alkyl (e.g. methyl), C_{1-3} alkoxy (e.g. methoxy), phenyl or nitro groups.

A particularly preferred compound of formula (A) is tebuconazole:
alpha-[2-(4-chlorophenyl)ethyl]-alpha(1,1-dimethylethyl)-1H-1,2,4-triazole-1-ethanol.

Alternatively, the triazole compound is advantageously selected from compounds of formula (B):



(B)

wherein R_3 is as defined for R_2 above and R_4 represents a hydrogen atom or a branched or straight chain C_{1-5} alkyl group (e.g. n-propyl).

Particularly preferred triazole compounds of this type are: propiconazole (1-[[2-(2-4-dichlorophenyl)-4-propyl-1,3-dioxolan-2-yl]methyl]-1H-1,2,4-triazole) and azaconazole (1-[[2,4-dichlorophenyl)-1,3-dioxolan-2-yl]methyl]-1H-1,2,4-triazole. Other triazoles which could be used include hexaconazole ((RS)-2-(2,4-dichlorophenyl)-1-(1H-1,2,4-triazol-1-yl)hexan-2-ol), difenaconazole, cyproconazole ((2RS,3RS; 2RS,3SR)-2-(4-chlorophenyl)-3-cyclopropyl-1-(1H-1,2,4-triazol-1-yl)butan-2-ol), bromuconazole (1-[4-bromo-2-(2,4-dichloro-phenyl)tetrahydrofurfuryl]-1*H*-1,2,4-triazole), epoxiconazole (1-[3-(2-chlorophenyl)-2-(4-fluorophenyl)oxiran-2-ylmethyl]-1*H*-1,2,4-triazole), metconazole (5-[(4-chlorophenyl)-methyl]-2,2-dimethyl-1-(1*H*-1,2,4-triazol-1-ylmethyl)cyclopentanol), and triticonazole ((E)-5-(4-chloro-phenyl)methylene)-2,2-dimethyl-1-(1*H*-1,2,4-triazol-1-ylmethyl)-cyclopentanol),

fenbuconazole, flusilazole, tetraconazole and penconazole.

Compositions according to the invention may contain more than one triazole compound, for example, they may contain two or more triazoles selected from tebuconazole, propiconazole, azaconazole and cyproconazole, such as tebuconazole and propiconazole, tebuconazole and cyproconazole or a mixture of tebuconazole, propiconazole and azaconazole.

Of the quaternary ammonium compounds which may be used in the compositions and methods of the present invention, suitable compounds include:

1. Monoalkyltrimethyl ammonium salts of formula (III):

$$\begin{array}{ccccc} & & CH_3 & & \\ & & | & & \\ R & - & N^+ & - & CH_3 \;.\; X^- \\ & & | & & \\ & & CH_3 & & \end{array} \qquad \text{(III)}$$

wherein R is an alkyl group having between 6 and 18 carbon atoms, preferably between 12 and 14 carbon atoms and X^- is an anion chosen to allow ready water solubility of the quaternary ammonium salt. Examples being : chloride, bromide, sulphate, acetate, propionate, lactate, citrate, methosulphate and carbonate.

Preferred examples include Cocotrimethyl ammonium chloride in which the alkyl group R consists of a mixture of predominantly C_{12} and C_{14}.

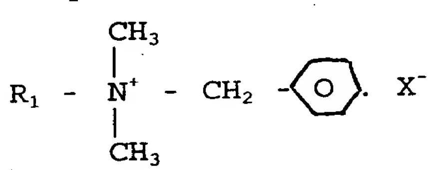
2. Dialkyl dimethyl ammonium salts of formula (IV):

$$\begin{array}{ccccc} & & CH_3 & & \\ & & | & & \\ R_1 & - & N^+ & - & CH_3 \;.\; X^- \\ & & | & & \\ & & R_2 & & \end{array} \qquad \text{(IV)}$$

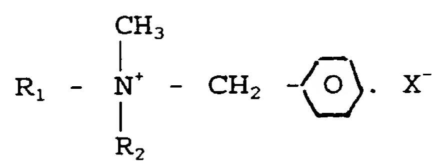
wherein R_1 and R_2 are alkyl groups which may be the same or different and which contain between 6 and 18 carbon atoms, preferably between 8 and 10 carbon atoms and X^- is an anion of the type previously described.

Preferred examples include Didecyl dimethyl ammonium chloride, dioctyl dimethyl ammonium chloride and octyl decyl dimethyl ammonium chloride either individually or as a mixture containing two or three of these.

3. Alkyl dimethyl benzyl ammonium salts and dialkyl methyl benzyl ammonium salts of formulae (V) or (VI).



(V)



(VI)

wherein R_1 and R_2 are alkyl groups which can be the same or different and which contain between 6 and 18 carbon atoms, preferably between 8 and 10 carbon atoms in a dialkyl compound and between 10 and 14 carbon atoms in a monoalkyl compound and X^- is an anion of the type previously described.

Preferred examples include Coco benzyl dimethyl ammonium chloride and dicoco benzyl methyl ammonium chloride in which the alkyl groups are predominantly C_{12} and C_{14}.

4. Alkyl and dialkyl oxyethylene methyl ammonium salts of formulai (VII) or (VIII):

$$\begin{array}{c} \quad CH_3 \\ \quad | \\ R_1 - N^+ - CH_3.X^- \\ \quad | \\ \quad (CH_2-CH_2O)_mH \end{array}$$

(VII)

$$\begin{array}{c} \quad CH_3 \\ \quad | \\ R_1 - N^+ - R_2.X^- \\ \quad | \\ \quad (CH_2-CH_2O)_mH \end{array}$$

(VIII)

wherein R_1 and R_2 are alkyl groups which may be the same

or different and which contain between 6 and 18 carbon atoms, preferably between 8 and 10 carbon atoms in a dialkyl compound and between 10 and 14 carbon atoms in a monoalkyl compound, most preferably 10 carbon atoms. m is a number between 1 and 20 typically between 1 and 8, preferably between 3 and 5. X^- is an anion of the type previously described, preferably propionate or lactate.

Preferred examples include N,N-didecyl-N-methyl-poly(oxyethyl) ammonium propionate (Bardap 26) or N,N-didecyl-N-methyl-poly(oxyethyl) ammonium lactate.

5. Polymeric quaternary ammonium compounds in which active quaternary ammonium compounds are chemically grafted to a polymer backbone.

Compositions containing quaternary ammonium compounds can form micro-emulsions which are particularly useful in the treatment of timber. In addition, the presence of these compounds means that additional organic solvents may not be necessary to solubilise the triazole compound if such a compound is also present in the formulation. The inclusion of quaternary ammonium compounds may also improve penetration of the triazole compound into the timber.

The optimum weight ratio of the oxathiazine compound to the other organic biocide varies depending on the particular material to when the composition is applied, the type of organism against which protection is required and the precise conditions to which the treated material will be exposed. However, preferably, the weight ratio of oxathiazine compound to triazole and/or quaternary ammonium compound should be between 100:1 and 1:100 or 50:1 and 1:50, more preferably between 20:1 and 1:20 or 5:1 and 1:10, typically between 2:1 and 1:5. In certain preferred formulations according to the invention, the quarternary ammonium compounds will be present in excess of the oxathiazine

or triazole compound. The triazole and oxathiazine compound may be present in about equal amounts (e.g. 2:1 to 1:2 on a weight basis) and at least as much quarternary ammonium compound may be present, either as much as one of the other ingredients or as much as both of them together. For example, the ratio of quaternary ammonium compound to oxathiazine may advantageously be 1:1 to 8:1 preferably 2:1 to 5:1 on a w/w basis.

The concentration of the formulation required for preservative treatment depends on the ratio of oxathiazine to triazole or quaternary ammonium compound selected, the method of treatment employed, the timber species, the level of protection required and the nature and quantity of any other biocides present. The amounts necessary can be determined readily by one skilled in the art. In general, the amount of oxathiazine will be in the range 0.01-1.0 kgm^{-3}, the amount of triazole in the range 0.1-10.0 kgm^{-3} and the amount of quaternary ammonium compound will be in the range 0.1-10.0 kgm^{-3}; all values are expressed as the weight per unit volume of wood treated.

Conveniently, the compositions of the present invention are applied as a liquid composition, preferably by high pressure impregnation. They may also be applied as a solid implant or paste. Preferably, when applied in liquid form, this is in an aqueous solution, but one or more organic solvents or a mixture of water and an organic solvent could also be used. Suitable organic solvents include both aromatic and aliphatic hydrocarbon solvents such as white spirit, petroleum distillate, kerosene, diesel oils and naphthas. Also, benzyl alcohol, 2-phenoxy ethanol, methyl carbitol, propylene carbonate, benzyl benzoate, ethyl lactate and 2-ethyl hexyl lactate. Formulations can be prepared as concentrates intended to be diluted at the treatment facility, or the formulations can be prepared in the form of dilute treatment solutions.

The compositions according to the invention may additionally, comprise other active ingredients such as termiticides, insecticides, bacteriocides and other fungicides. Suitable additional fungicides would be apparent to one skilled in the art and will vary according to the application. In particular, additional fungicides which extend the spectrum of activity of the formulation may be chosen, such as fungicides active against bluestain fungi, white rots, brown rots, dry rots and moulds. Suitable additional fungicides include for example, dichlofluanid, acypetacs, imazalil, IPBC, isothiazolones, tolylfluanid, chlorothalonil, benzimadazoles, as well as metal compounds such as copper, Cu-oxide and Cu-HDO, also iron and zinc and salts, compounds and soaps thereof. Suitable insecticides would also be apparent to the skilled man depending upon the intended application, and include, for example, chlorpyrifos, cypermethrin, fenvalerate, fipronil, farox, teramethrin, isofenphos, permethrin, silafluofen, deltamethrin, bifenthrin, cyfluthrin and imidacloprid, and benzoylureas such as lufenuron, hexaflumuron and flufenoxuron and in particular, flurox.

The compositions according to the invention may additionally comprise other components which may act to improve the characteristics of the wood treated with these biocides. Such compounds could include water repellents based on waxes, silicones and polysiloxanes, latex, fluorocarbon, organic carboxylate/metals, paper sizing agents or amine oxides, or combinations thereof; crosslinking agents based on alkyds, acrylics, polyurethanes, formaldehydes, dimethylol, and epichlorohydrin or combinations thereof. Oils may also be used as may UV absorbers, corrosion inhibitors and defoamers.

The following non-limiting Examples further illustrate the invention.

A: Examples of formulations according to the invention for use in the preservation of wood and other materials

Those formulations which do not contain water are preferably made by weighing together all the components and blending to produce clear homogenous systems. Heating to not above 50°C may be necessary to ensure rapid dissolution of the solid active components in the solvents. Alternative methods of manufacture are possible such as solubilising the active components in water with surfactants.

Oil in water emulsions or micro-emulsions of these formulations can be prepared by adding the concentrates prepared as above to water at room temperature with good agitation to ensure proper dispersion. Emulsions containing any desired level of active component can be prepared in this way.

Those formulations containing water are formed into concentrated emulsions by taking firstly the non water containing components and blending them as for the anhydrous formulations. The required water is then added to the other components after the temperature has been allowed to return to ambient with efficient stirring to produce the concentrated emulsion. These emulsions can later be diluted to the required strength simply by adding to more water with mixing to produce diluted emulsions.

In the following Examples, Bardap 26 refers to N,N-didecyl-N-methyl-poly(oxyethyl) ammonium propionate. In all cases, the Bardap 26 preparation contains 70% of active ingredient.

Example 1

BARDAP 26/BETHOXAZIN/CYPROCONAZOLE 10:2:1

	% w/w
Bardap 26	14.29
Bethoxazin	2.00
Cyproconazole	1.00
Methyl diethoxol	66.71
Nonylphenol 12EO	16.00

Example 2

BETHOXAZIN/CYPROCONAZOLE 2:1

	% w/w
Bethoxazin	1.334
Cyproconazole	0.666
Methyl diethoxol	18.000
Dowanol PnB	10.000
Mineral oil	60.000
Tridecanol 10EO	10.000

Example 3

BARDAP 26/BETHOXAZIN/TEBUCONAZOLE/PROPICONAZOLE 10:2:0.5:0.5

	% w/w
Bardap 26	14.29
Bethoxazin	2.00
Tebuconazole	0.72
Propiconazole	0.72
Butyl glycollate	15.35
Dioctyl phthalate	46.92
Nonyl phenol 9EO	20.00

Example 4

BARDAP 26/BETHOXAZIN 10:2

	% w/w
Bardap 26	14.29
Bethoxazin	2.00
Dowanol DPM	21.79
Aromatic solvent	44.42
Castor oil 65EO	17.5

Example 5

BETHOXAZIN/TEBUCONAZOLE/PROPICONAZOLE 2:1:1

	% w/w
Bethoxazin	2.50
Tebuconazole	1.25
Propiconazole	1.25
Benzyl alcohol	14.60
Methyl octoate	58.40
Castor oil 40EO	22.00

Example 6

BETHOXAZIN/TEBUCANOZOLE 2:1

	% w/w
Bethoxazin	3.33
Tebuconazole	1.67
Butyl glycollate	23.10
Dioctyl phthalate	53.90
Nonylphenol 12EO	18.00

Example 7

BARDAP 26/BETHOXAZIN/IRON 10:2:1

	% w/w
Bardap 26	14.29

Bethoxazin	2.00
Iron naphthenate*	10.00
Oleyl alcohol 5EO	5.00
Oleyl alcohol 10EO	7.50
Dowanol PnB	15.00
Mineral oil	46.21

* Iron naphthenate in solvent containing 10.00% w/w iron metal

Example 8

BARDAP 26/BETHOXAZIN/IRON 10:2:1
Using complexed iron compound

	% w/w
Bardap 26	14.29
Bethoxazin	2.00
Iron EDTA*	11.11
Butyl glycollate	23.36
Tridecanol 15EO	12.50
Water	36.74

* Contains 9.0% w/w iron metal

Example 9

BARDAP 26/BETHOXAZIN/CYPROCONAZOLE/COPPER 10:2:1:1

	% w/w
Bardap 26	7.15
Bethoxazin	1.00
Cyproconazole	0.50
Copper gluconate*	3.57
Methyl diethoxol	14.50
Dowanol PnB	25.65
Tridecanol 13EO	15.00
Water	32.63

* Contains 14% copper metal

Example 10

BARDAP 26/BETHOXAZIN/Cyproconazole 10:2:1 plus Flurox

	% w/w
Bardap 26	14.28
Bethoxazin	2.00
Cyproconazole	1.00
Flurox	1.00
Methyl diethoxol	65.71
Nonyl phenol 12EO	16.00

Example 11

BARDAP 26/BETHOXAZIN + Farox 10:2 plus Farox

	% w/w
Bardap 26	14.28
Bethoxazin	2.00
Farox	1.50
Dowanol DPM	21.29
Aromatic solvent	43.42
Castor oil 65EO	17.51

Example 12

BETHOXAZIN/Tebuconazole 2:1 + Cypermethrin

	% w/w
Bethoxazin	3.33
Tebuconazole	1.67
Cypermethrin	2.00
Butyl glycolate	22.10
Dioctyl phthalate	52.90
Nonyl phenol 12EO	18.00

Example 13

Bardap 26/BETHOXAZIN/Iron 10:2:1 + Cyfluthrin

	% w/w
Bardap 26	14 29
Bethoxazin	2.00
Cyfluthrin	1.00
Iron EDTA*	11.11
Butyl glycolate	22.86
Tridecanol E015	12.00
Water	36.74

* contains 9% w/w iron metal.

Example 14

BARDAP 26/BETHOXAZIN/TEBUCONAZOLE/PROPICONAZOLE 10:2:0.5:0.5

	% w/w
Bardap 26	14.29
Bethoxazin	2.00
Tebuconazole	0.5
Propiconazole	0.5
Butyl glycollate	15.79
Dioctyl phthalate	46.92
Nonyl phenol 9EO	20.00

Synergistic action of mixtures formulated according to the invention

The toxic limit value for a particular biocidal compound is the concentration of the compound which is required to prevent degradation (defined as >3% mass loss) of a substrate by a target organism. Toxic limits are normally expressed as two experimentally-determined

concentrations that span the pass/fail point of the test. The toxic index is the midpoint of these two values. Where a preservative composition contains two biocidal compounds at a particular ratio, the toxic index is the estimated minimum concentration of each biocide required for effective protection of the substrate from the target organism. In Figure 1 of the accompanying drawings, points A and B are the toxic index values for biocidal compounds Y and X respectively and the straight line between these two points illustrates the toxic index values which would be obtained if the biocidal effects of compounds X and Y are merely additive. If, for any particular ratio of X:Y, the toxic index value is found to be below the straight line (e.g. at point C), then compounds X and Y are synergistic at that particular ratio.

A convenient method of assessing the synergistic properties of a formulation is to use a 'synergistic index'. This may be defined as:

$$\text{Synergistic Index (SI)} = \frac{\text{Theoretical toxic index}}{\text{Actual toxic index}}$$

The theoretical toxic index may be calculated by interpolation to the theoretical line of action. A SI of 1 indicates no synergism. As the SI increases, so the degree of synergism also increases.

B: <u>Wood Preservative Efficacy</u>

Testing was carried out to determine the performance of active ingredients alone and in mixture using a soft rot soil burial method. The method used is similar to that described by the European pre-standard ENV-807 and challenges the treated wood in a wet soil environment to soft rot fungi belonging to the groups *Ascomycotina* and

Deuteromycotina.

Beech (*Fagus sylvatica*) blocks measuring 5 x 15 x 30 mm were prepared from local grown, seasoned, knot-free sapwood. After oven drying and weighing, the blocks were vacuum impregnated (in groups of 6 replicates) with retentions of the test preservatives which had been freshly prepared using deionised water as the diluent.

The following preservative combinations were tested:

Bethoxazin/Propiconazole (1:1)
Bethoxazin/Propiconazole/Tebuconazole (2:1:1)
Bethoxazin/Bardap 26 (1:5)
Bethoxazin/Bardap 26/Cyproconazole (2:10:1)

After treatment, the blocks were covered with polythene for a period of one week to reduce the drying rate and allow any fixation reactions to occur. They were then fully ventilated by standing on the laboratory bench for 2 weeks and allowed to dry.

Each series of blocks was then exposed in John Innes (No. 2) compost, previously wetted to 110% of water holding capacity using deionised water. The test systems were then incubated for 14 weeks at 28°C.

Following incubation, blocks were removed from the soil, gently rinsed in clean water and then oven dried and re-weighed.

Preservative retention and weight change data were calculated for each block and the results expressed as toxic limit values according to the criteria laid down in the test method EN113.

Results of Efficacy Testing

The results of the efficacy tests are given in the following table and expressed as toxic limit values in kgm^{-3} active ingredient retention.

Table 1

Results of Soil Testing with Organic Biocides	
Fungicide	Toxic Limit Value (kgm^{-3})
Tebuconazole	> 7.0
Propiconazole	> 7.0
Bethoxazin	> 0.77
Bethoxazin/Propiconazole	0.65-0.74
(1:1)	0.15-0.32
Bethoxazin/Propiconazole/ Tebuconazole (2:1:1)	0.54-1.11
Bethoxazin/Bardap 26 (1:5)	> 6.2
Bardap 26	0.58-1.18
Bardap 26/Bethoxazin/ Cyproconazole (10:2:1)	

A Toxic Limit Value of $>7.0kgm^{-3}$ indicates that at the concentrations tested, the highest of which was $7.0kgm^{-3}$, no effective protection of the wood was achieved.

Using the conventions of EN113, the following toxic limit values are expressed as individual active ingredients and mixtures. Therefore, taking tebuconazole as an example, the table below shows that the amount of tebuconazole required for effective preservation dropped from $>7kgm^{-3}$ when applied on its own to $0.08kgm^{-3}$ when it was part of a Bethoxazin/ Propiconazole/Tebuconazole mixture.

Table 2

Fungicide	Effective Retention of					
	Tebuconazole	Cyproconazole	Propiconazole	Bethoxazin	Bardap 26	Mixture
Bethoxazin	-		-	>0.77	-	-
Tebuconazole	>7.0		-	-	-	-
Cyproconazole	-	1.25	-	-	-	-
Propiconazole	-		>7.0	-	-	-
Bethoxazin/ Propiconazole	-		0.345	0.345	-	0.69
Bethoxazin/Propiconazole/ Tebuconazole	0.8		0.08	0.16	-	0.32
Bethoxazin/Bardap 26	-		-	0.185	0.925	1.11
Bardap 26	-		-	-	>6.2	-
Bardap/Bethoxazin/ Cyproconazole	-	0.068	-	0.14	0.68	0.88

Where the lower toxic limit value provides a weight loss of 10% m/m or greater, then the upper toxic limit value has been used to indicate the probable effective retention of preservative; this is in accordance with EN113.

From this data, it can be seen that combinations of these organic biocides with Bethoxazin provide a significant enhancement in preserving ability towards microfungi that attack wood in contact with soil. The oxathiazine and the triazole/quaternary ammonium compound work synergistically to protect the wood substrate from fungal attack.

The results have been plotted in Figures 2, 3, 4 and 5 which show expected effect of combining the various biocides at the ratios tested with the actual results obtained for the combinations of biocides.

A further demonstration of synergism can be derived by

calculating a synergistic index value (SI) as described above. This compares the toxic threshold obtained in the test (Table 3) with the theoretical values which can be derived from Figures 2-5.

These results are provided in the following table.

Table 3

Formulation	Toxic threshold value (kgm^{-3} ai)	Theoretical value (kgm^{-3} ai)	Synergistic Index (SI)
Bethoxazin/ Propiconazole (1:1)	0.69	1.4	2.03
Bethoxazin/Propiconazole/ Tebuconazole (2:1:1)	0.32	1.4	4.37
Bethoxazin/Bardap 26 (1:5)	1.11	2.7	2.43
Bardop 26/Bethoxazin/ Cyproconazole	0.89	1.065	1.20

These values clearly show significant synergism at the ratios tested. In the case of the 3-way combination, some additional synergy is noted over and above that derived from either a combination of Bethoxazin plus azole or Bethoxazin plus Bardap 26.